



Satellite Assimilation Activities At NRL

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Naval Research Laboratory

- *Monterey - Marine Meteorology Division*
 - research and development of global, mesoscale and shipboard atmospheric analysis and prediction systems
- *Washington, D.C. - Remote Sensing and Space Sciences Divisions*
 - Upper atmosphere assimilation and modeling
 - Developed WindSat and POAM
- *Stennis Space Center, MS - Ocean Division*
 - Ocean data assimilation and modeling
- **Primary customer is Fleet Numerical Meteorology and Oceanography Command (FNMOC)**
 - Provides weather support for Navy and Marine Corps, Air Force and other DoD activities
 - Produces and distributes products from numerical prediction models of the ocean and atmosphere



NRL/FNMOC Forecast Suite

- NOGAPS - Navy Operational Global Atmospheric Prediction System
 - Spectral T239, L30 with effective model top at 4 hPa
 - Operational forecasts out to 7 days
 - Provides input/boundary conditions for
 - mesoscale, ocean, wave and ice prediction models,
 - ensemble forecasting system
 - Aircraft and ship routing programs
 - tropical cyclone forecast model (GFDN)
 - Used for basic research predictability studies, adjoint sensitivity studies, adaptive observation-targeting
- COAMPS®* - Coupled Ocean/ Atmosphere Mesoscale Prediction System
 - nonhydrostatic; globally relocatable, nested grids; explicit prediction of moisture variables
 - 5-10 different operational areas

* COAMPS® is a registered trademark of the Naval Research Laboratory, Monterey CA



NRL/FNMOC Analysis Systems

- NAVDAS - NRL Atmospheric Variational Data Assimilation System
 - 3dvar observation space algorithm
 - Unified code for both global and mesoscale NWP systems
 - Operational for NOGAPS on October 1, 2003
 - Operational for COAMPS® December, 2006
 - Designed to be precursor for NAVDAS-AR, our 4d accelerated representer assimilation system
 - Adjoint of NAVDAS is used for observation impact studies



Mesoscale and Global 4DVAR (NAVDAS-AR)

- NAVDAS-AR is under development
 - Observation space 4D-Var using cycling representer method
 - Weak-constraint formulation allows for model error to be included
 - “AR” stands for accelerated representer
 - Targeting for implementation into NOGAPS in late 2008
- Advantages of 4DVAR over 3DVAR
 - 4DVAR produces better NWP forecasts
 - Assimilation occurs over a time window of ~ 6 hours
 - Makes better use of asynoptic data
 - Observations are used at the correct time
 - More observations can be used
 - Uses surface and other single-level observations (e.g., ships, buoys, aircraft, UAVs, satellite wind vectors,...) more effectively
 - Flow dependent background and forecast model statistics



Satellite Assimilation Status

- **Operational**
 - AMSU-A operational (3 NOAA satellites)
 - Geostationary satellite winds - vis, IR and WV
 - MODIS polar winds (including direct broadcast winds)
 - WindSat vector winds and TPW
 - DMSP SSMI and SSMIS wind speed and TPW
 - QuikScat and ERS scatterometer wind vectors
- **Awaiting transition to OPS**
 - AMSU-B
 - HIRS
 - AQUA AIRS and AMSU
 - SSMIS
 - Assimilation of MW and IR radiances over land
- **Research assimilation**
 - MLS temperature, water vapor and ozone
 - CHAMP and COSMIC GPS
 - METOP IASI, AMSU, MHS



Verification Metrics

- **FNMOC NOGAPS unofficial score card**
 - 500 and 100 mb height anomaly correlation, NH and SH
 - 850 and 250 vector wind rms as verified against radiosondes
 - Tropical cyclone track forecast, verified against best track
- **FNMOC COAMPS unofficial score card**
 - Upper Air - RMS and mean bias of T, RH and wind speed versus radiosonde
 - Surface Temperature - RMS and mean bias of T versus screen temperatures
 - Precipitation amount - Equitable Threat Score using rain gauge data and/or quality controlled radar data as truth
- **Did we see improvement we hoped for?**
 - For example, assimilation of moisture information would improve humidity analysis and forecasts
- **How do we translate these numbers into what the customer wants?**



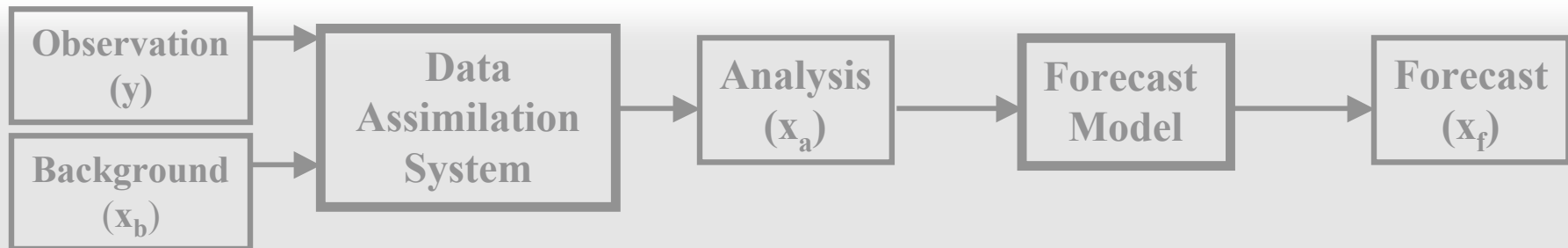
Observation Impact Methodology

- New mathematical technique using NAVDAS and NOGAPS adjoint models
- Observation impact generated once per day at 00 UTC
- Uses operational analysis fields and operational innovation vectors from NAVDAS / NOGAPS
- Results are used to
 - evaluate observation quality
 - tune observation reject lists
 - guidance for modifying assimilation procedures
 - Select AIRS channels for assimilation

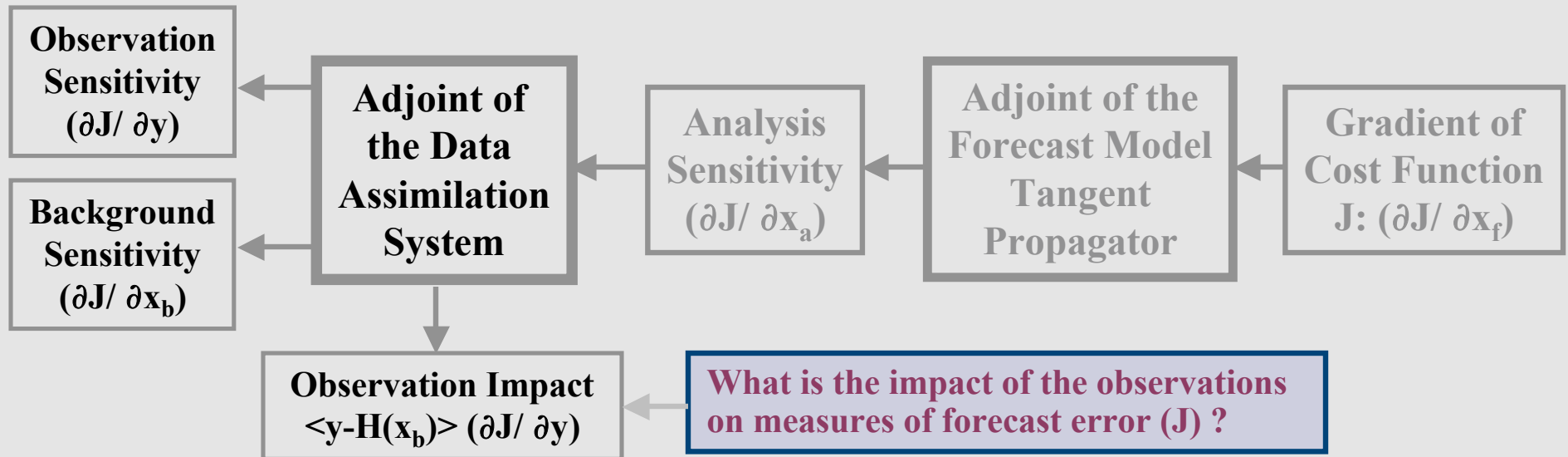
Baker and Daley (QJRMS, 2000)
Langland and Baker (Tellus, 2004)



NAVDAS Analysis - NOGAPS Forecast System

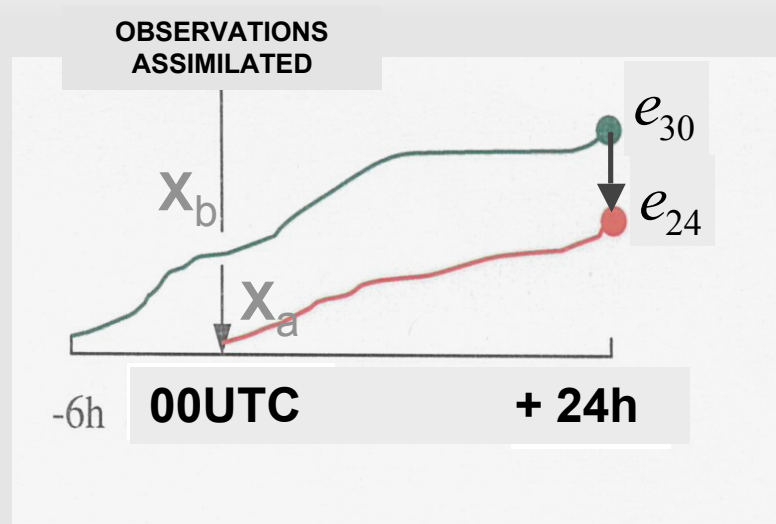


NAVDAS - NOGAPS Adjoint System





Observations, model trajectories and forecast error



Observations move the model state from the “**background**” trajectory to the new “**analysis**” trajectory

The forecast error difference, $e_{24} - e_{30}$, is due to the combined impact of all observations assimilated at 00UTC

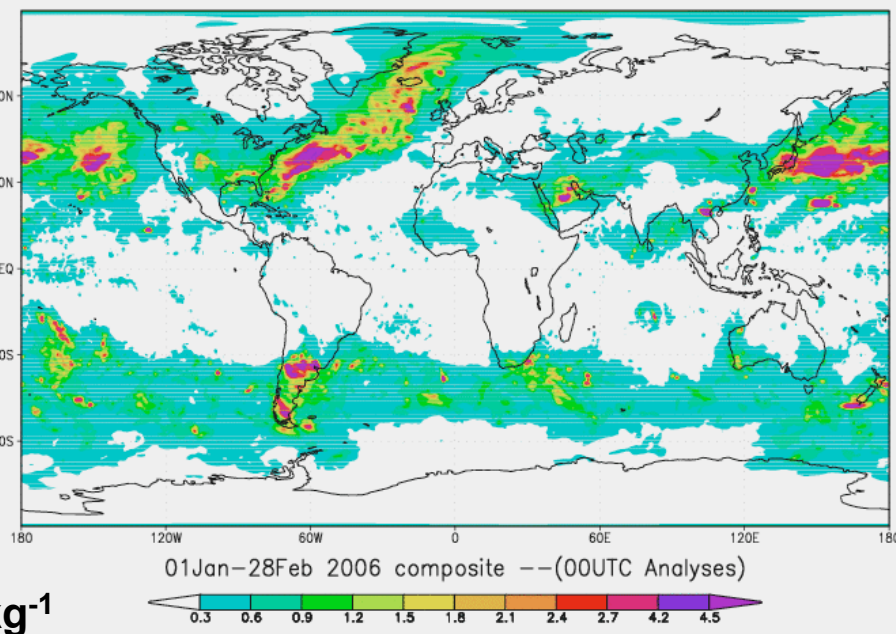
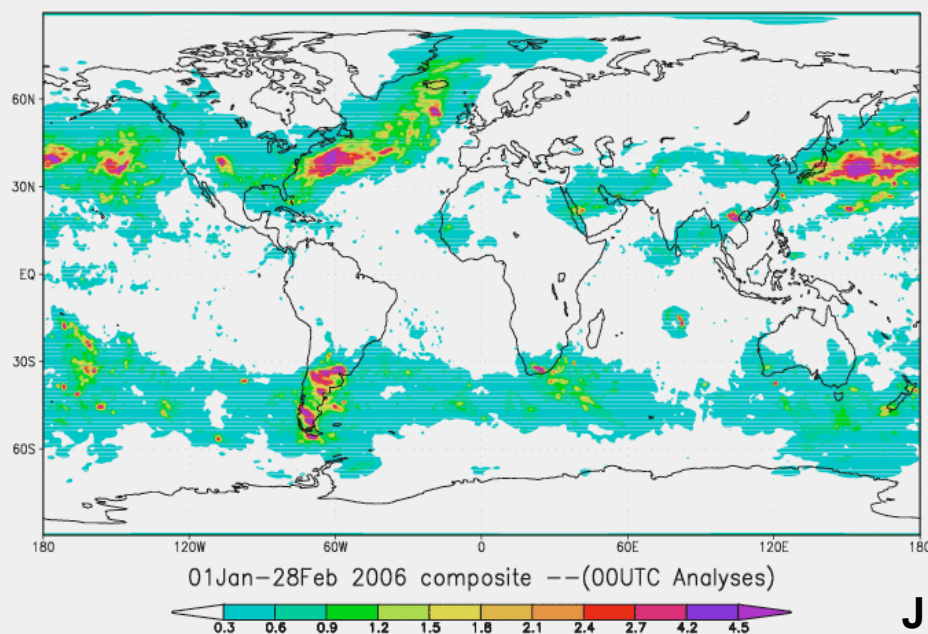


NOGAPS: sensitivity of forecast error to ICs

1 Jan – 28 Feb 2006

Energy-weighted sensitivity of e_{24} to X_a 00UTC

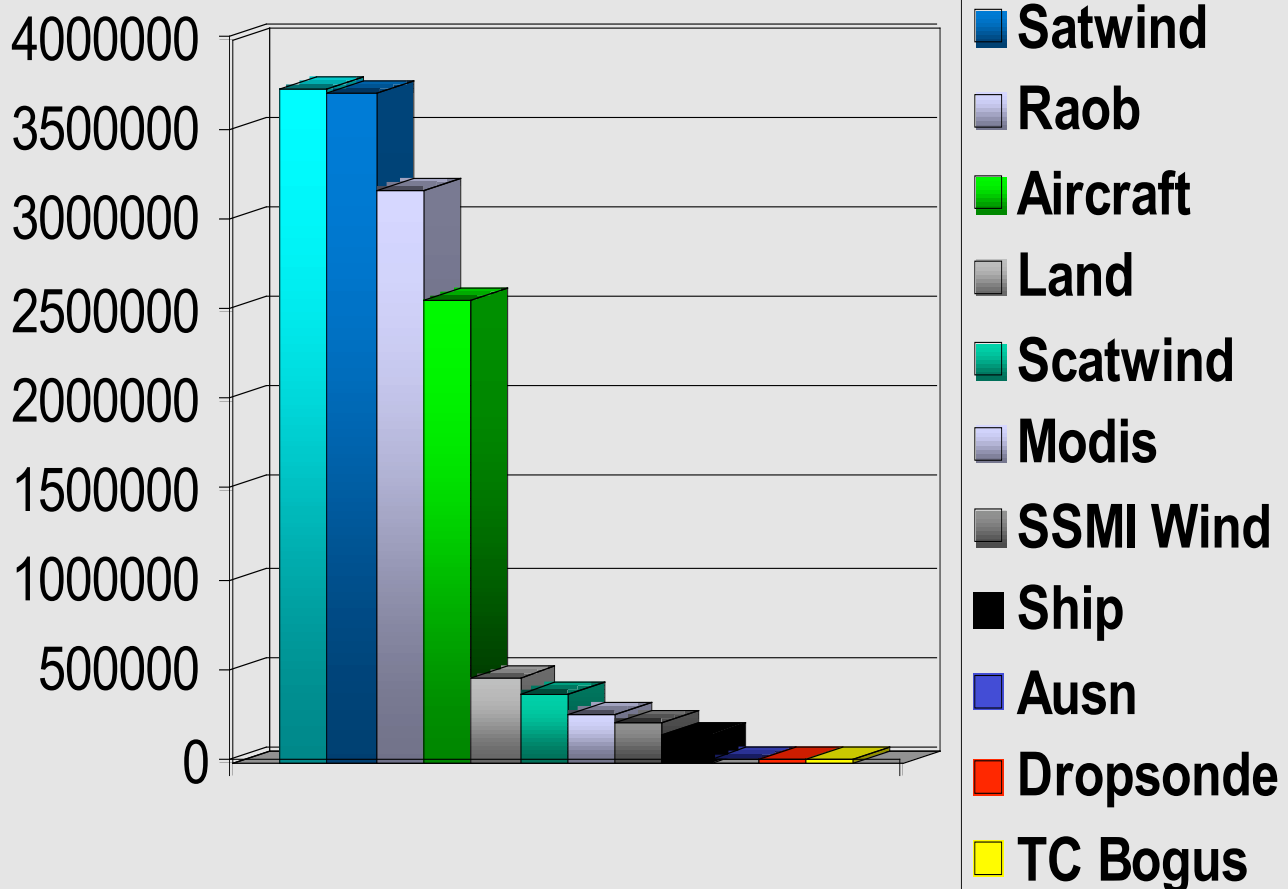
Energy-weighted sensitivity of e_{30} to X_b 18UTC





Instrument type data count

1 Jan – 28 Feb 2006
00UTC Analysis



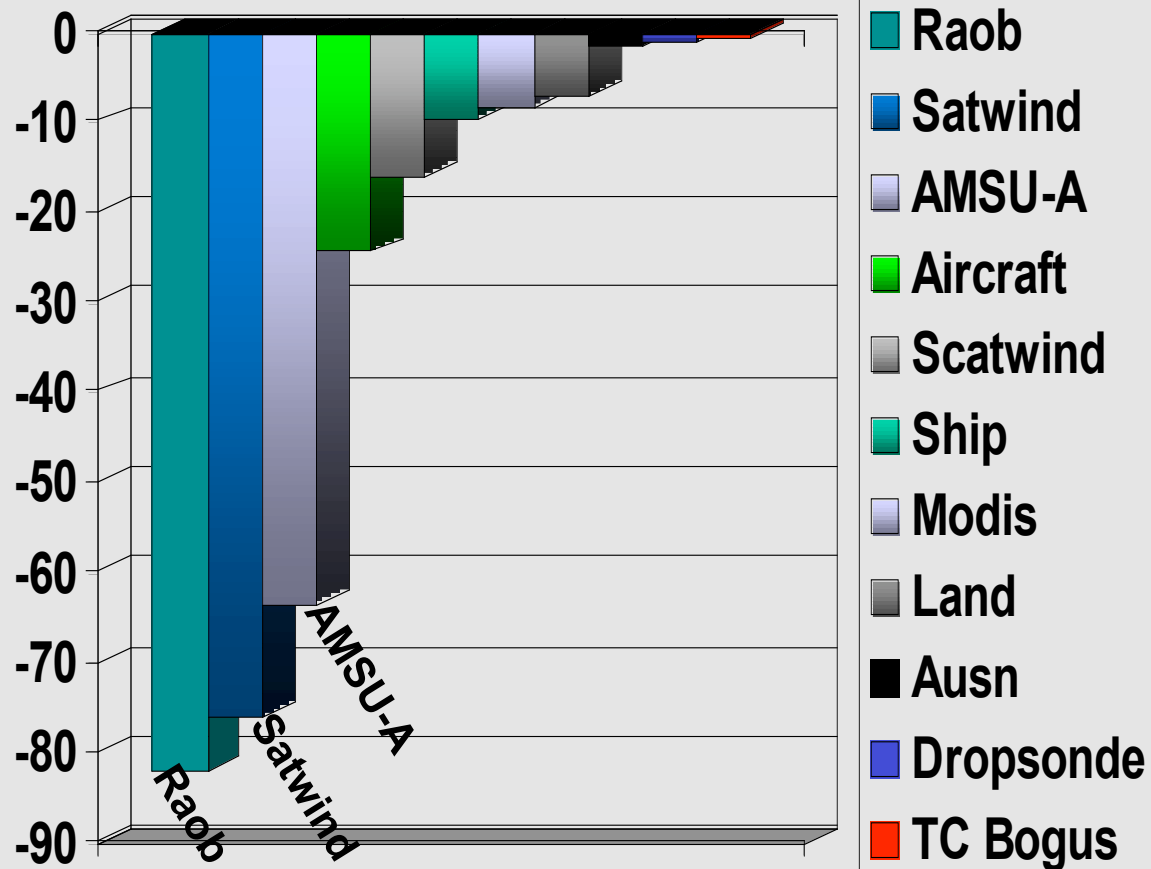


Total impact by observation type

Units of impact = J kg^{-1}

1 Jan – 28 Feb 2006
00UTC Analysis

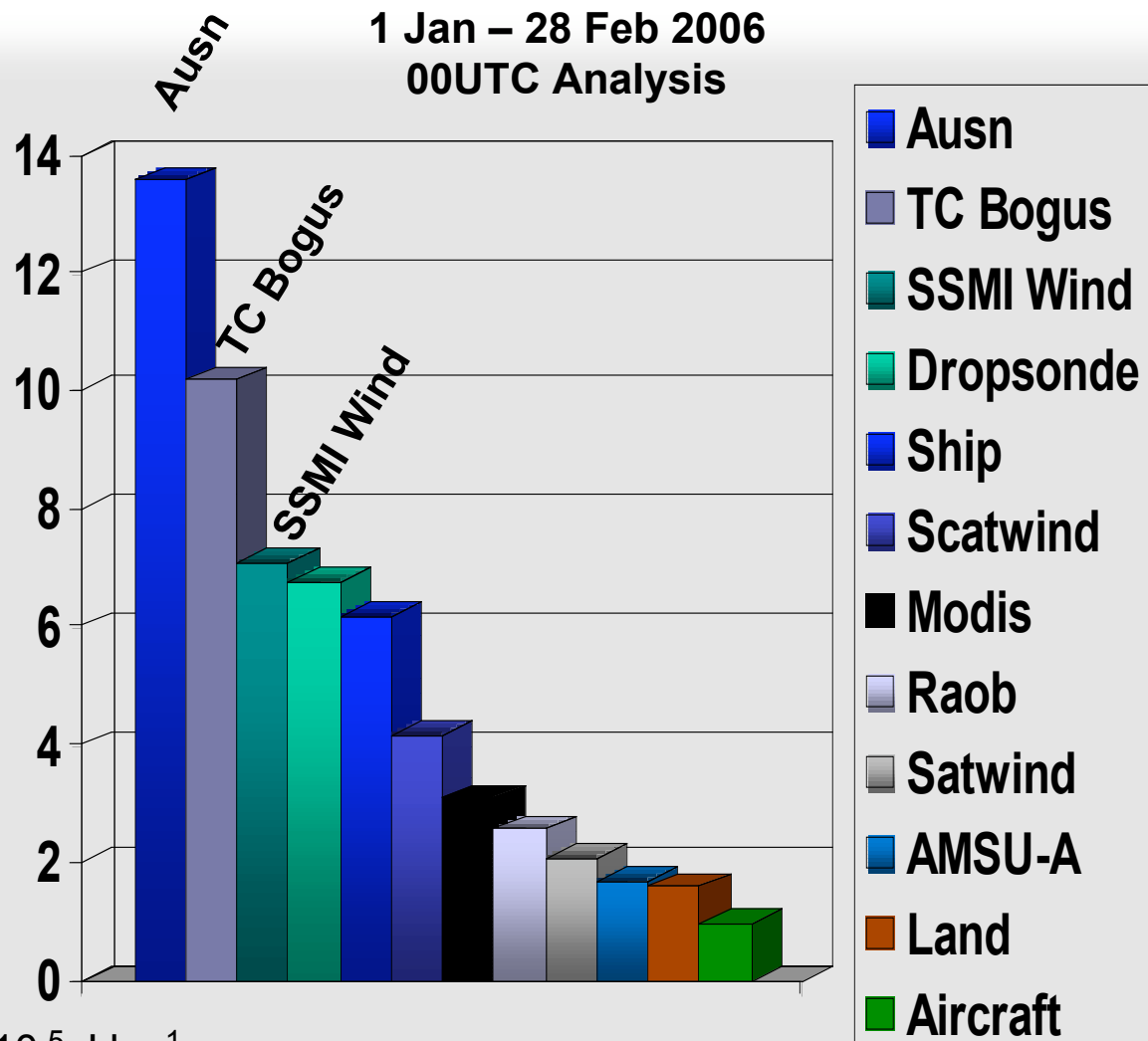
Beneficial
impact





Impact magnitude per observation by instrument type

1 Jan – 28 Feb 2006
00UTC Analysis

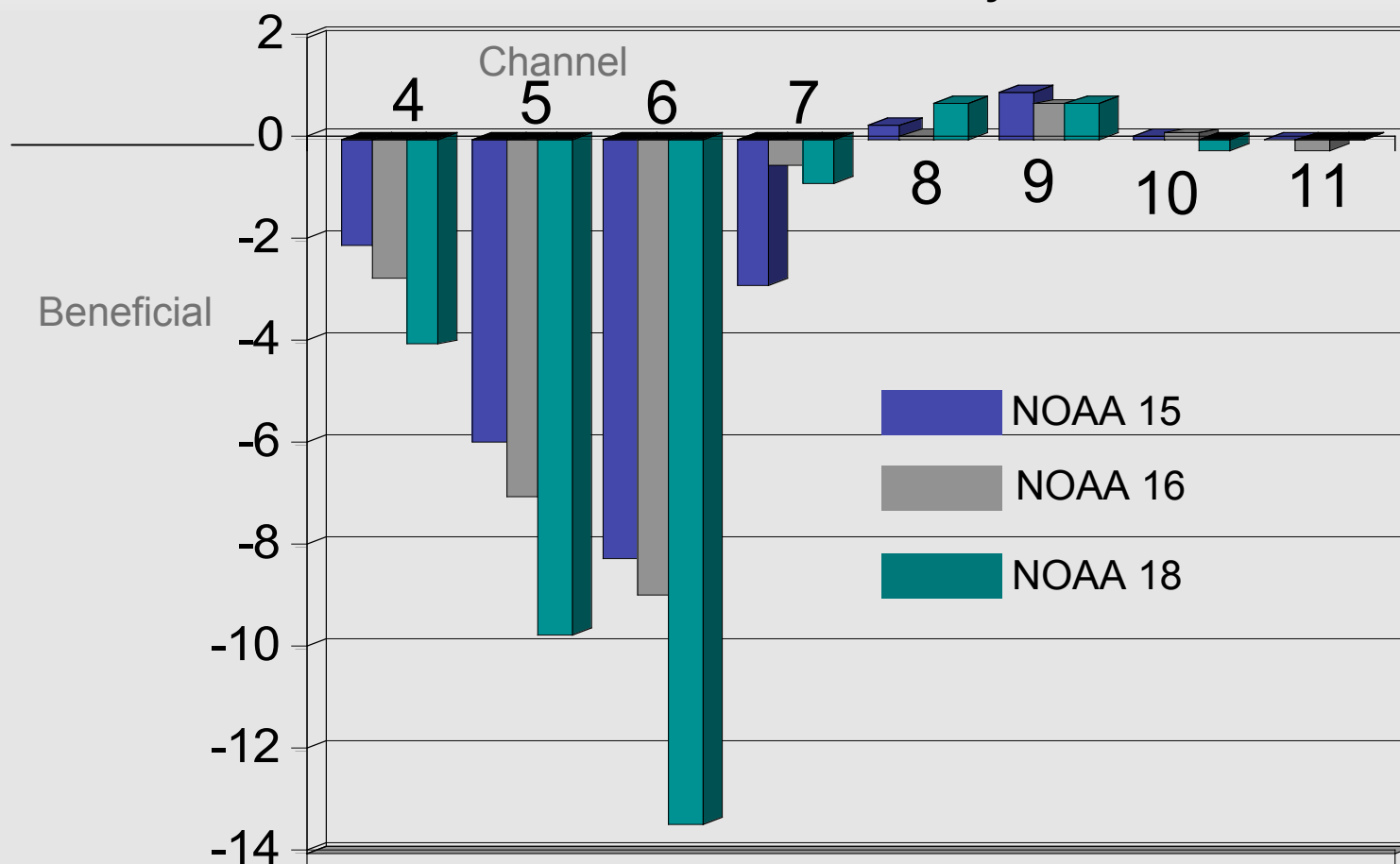




Impact for AMSU-A channels

1 Jan – 28 Feb 2006
00UTC Analysis

Units of impact = J kg^{-1}



Ch. peak near

11: 20mb

10: 50mb

9: 90mb

8: 150mb

7: 250mb

6: 350mb

5: 600mb

4: surface

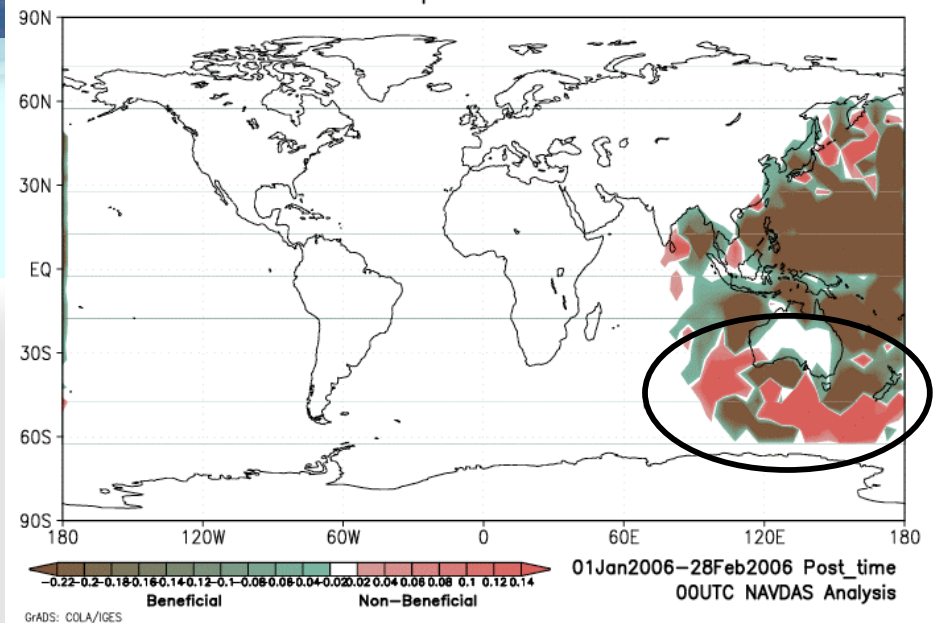
SATWIND data denial

Date: Jan-Feb 2006
Experiment

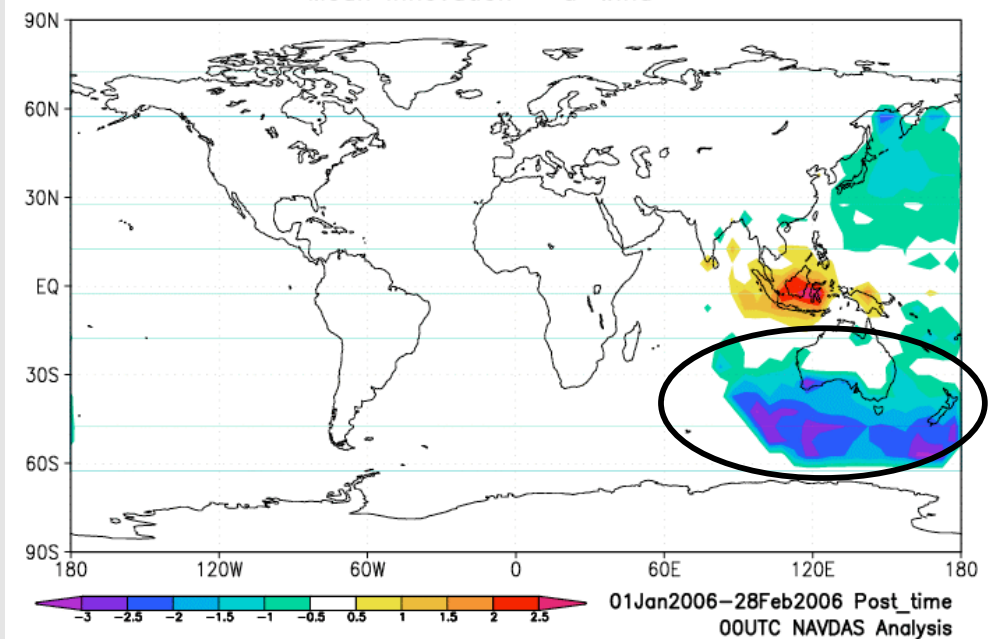
Issue: Large innovations and non-beneficial impact from satwinds at edge of coverage areas

Action Taken: Ob data removed if $> 39^\circ$ from satellite sub-point – gave 3-hr improvement in SHEM NOGAPS forecast skill

Type 58 SATWIND GMSC
Innovation Impact on 24h Fcst Error

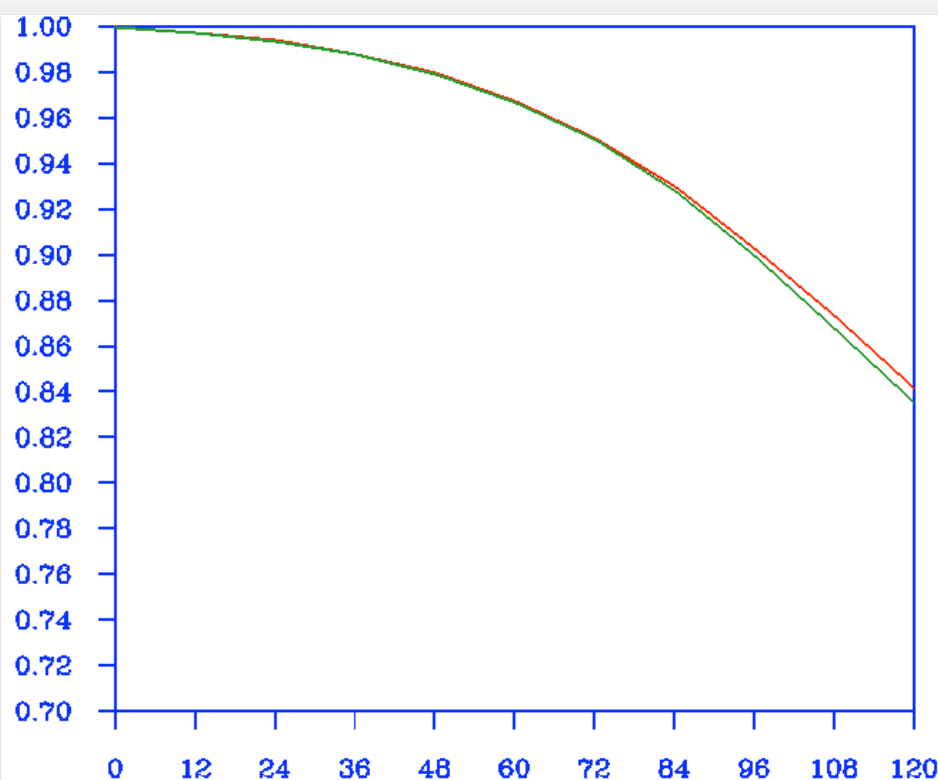


Mean Innovation – u-wind



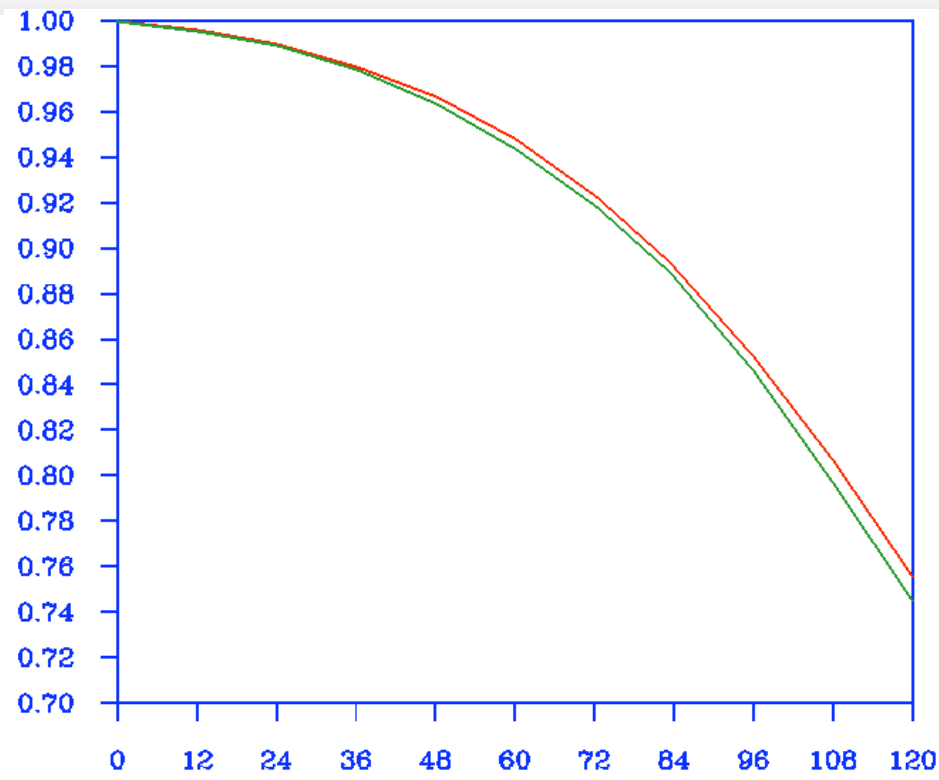


Restricting SSEC MTSAT Winds 500 mb Height Anomaly Correlation



Northern Hemisphere

Restricted Winds



Southern Hemisphere

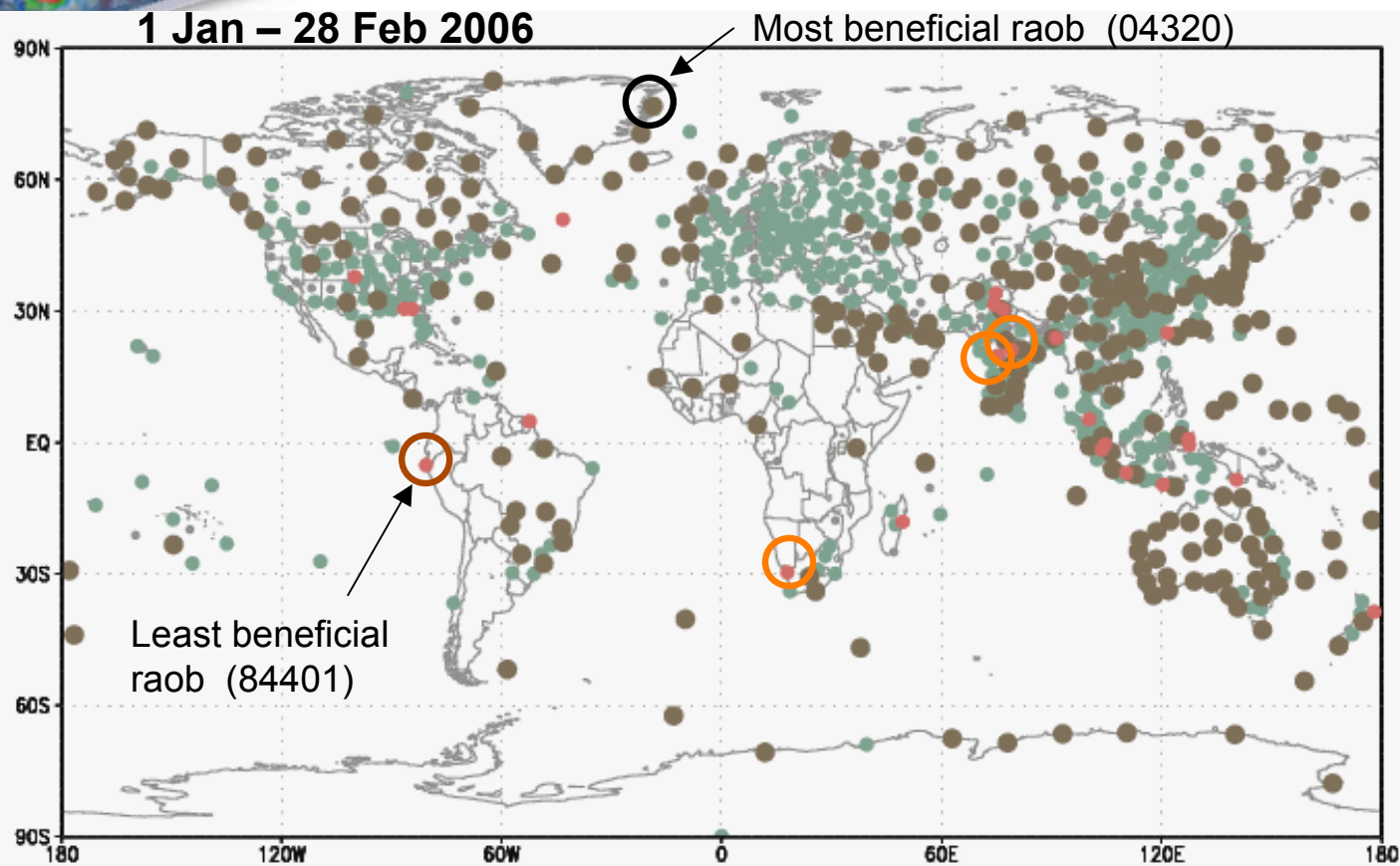
Control

February 16 – March 27, 2006

Radiosonde profile observation impact



1 Jan – 28 Feb 2006



- Most beneficial ($< -0.1 \text{ J kg}^{-1}$)
- Beneficial ($-0.01 \text{ to } -0.1 \text{ J kg}^{-1}$)
- Non-beneficial ($0.01 \text{ to } 0.1 \text{ J kg}^{-1}$)

○ On recent UKMO blacklist

Combines all separate temperature, wind, moisture, and height impacts at all levels of radiosonde profile

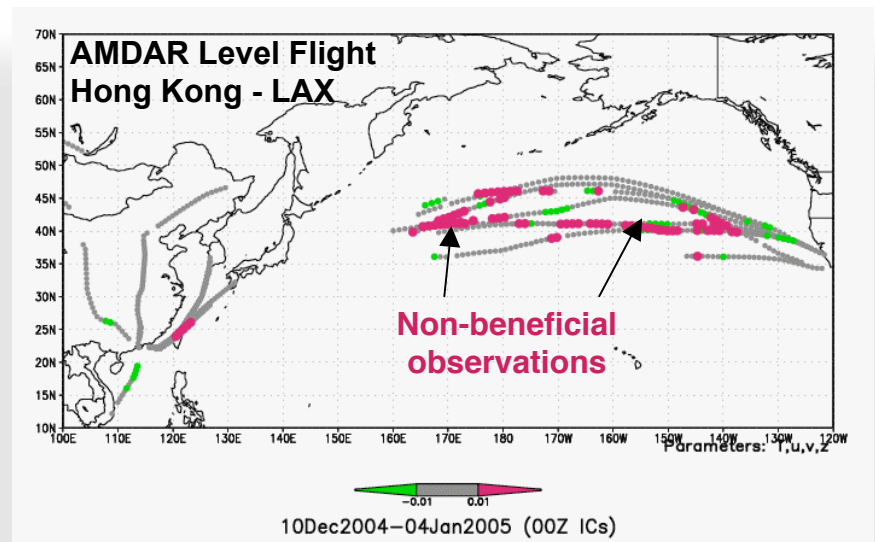


Isolated aircraft tracks

Date: First noticed Jan 05,
ongoing in several regions

Issue: aircraft flies in jet max
eastbound, outside of jet max
westbound: observation error
representativeness problem ?

Action Taken: HK0001
blacklisted by FNMOC (for a
while)





Aerosol Analysis and Prediction

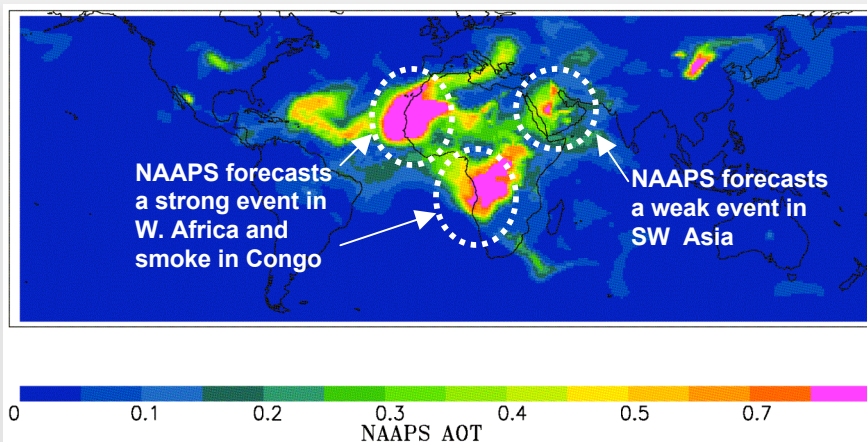
- NRL Aerosol Analysis and Prediction System (NAAPS)
 - Visibility and health risks
 - 4 species
 - Use NAVDAS to assimilate MODIS and AVHRR aerosol optical thickness (AOT) retrievals
- NAAPS (minus assimilation component) operational at FNMOC
 - 6-day forecast, four times a day (global),
 - 3-day forecast, twice per day (mesoscale)
- Products available on NRL Web site:
 - www.nrlmry.navy.mil/aerosol/



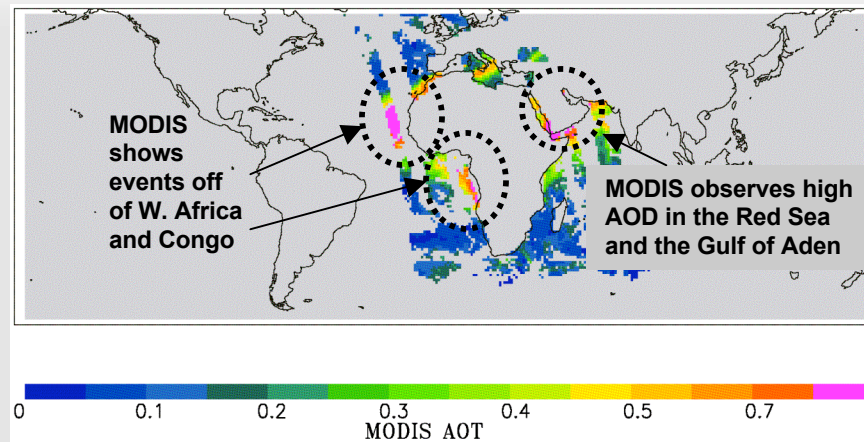
NAVDAS: Results for 12Z 19 July, 2005

Assimilation of MODIS optical depth

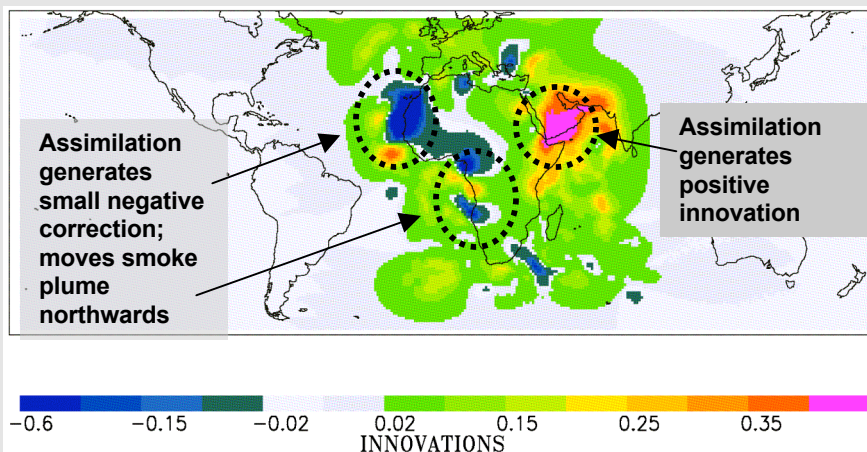
NAAPS first guess of AOD (12-h forecast) for 12Z, July 19, 2005



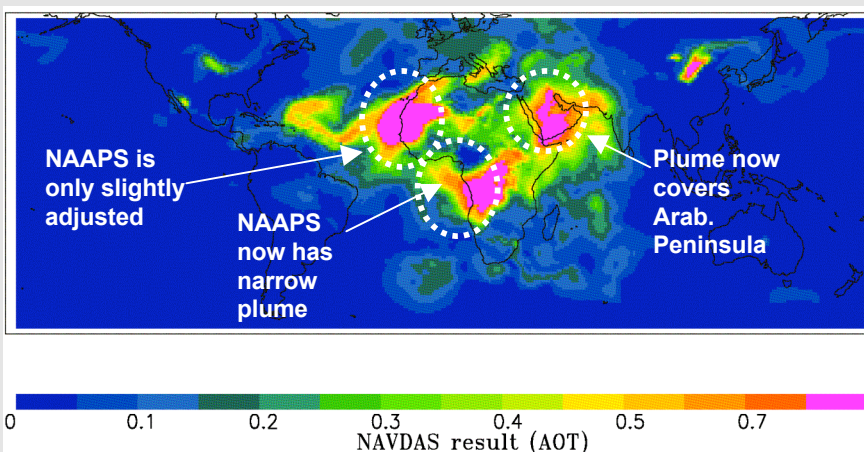
MODIS retrieved AOD for 09-15Z, July 19, 2005



NAVDAS Correction (NAAPS first guess + MODIS assimilation)



NAAPS updated AOD analysis (NAVDAS innovation + first guess)

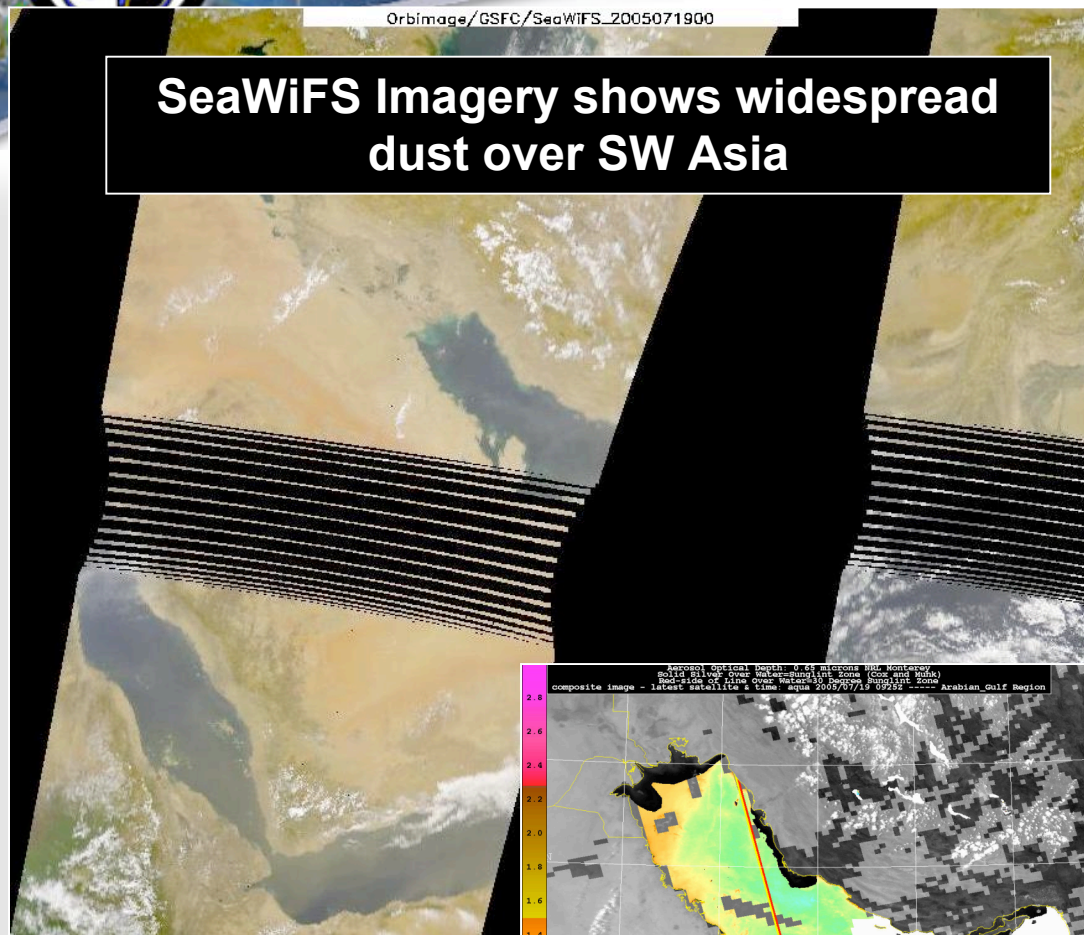




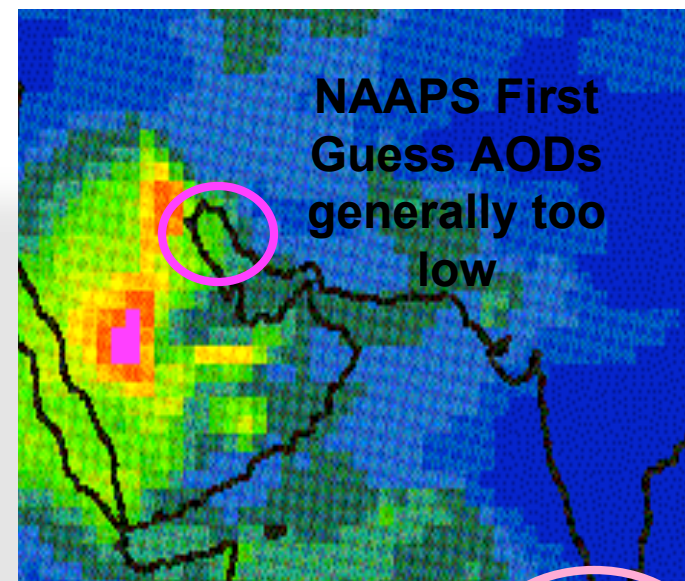
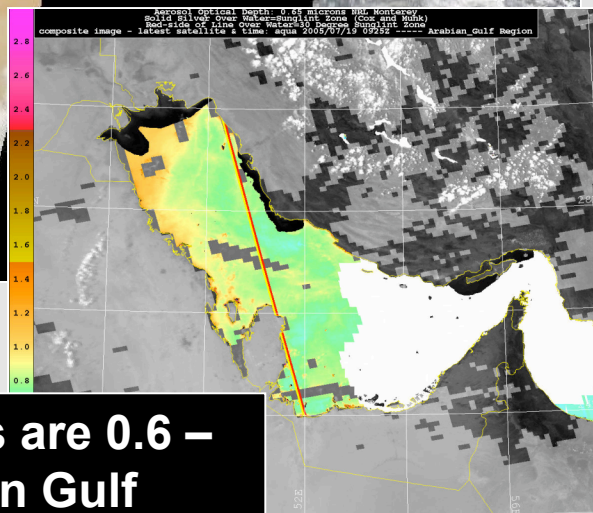
NAVDAS: Details for 12Z 19 July, 2005

Orbimage/GSFC/SeaWiFS_2005071900

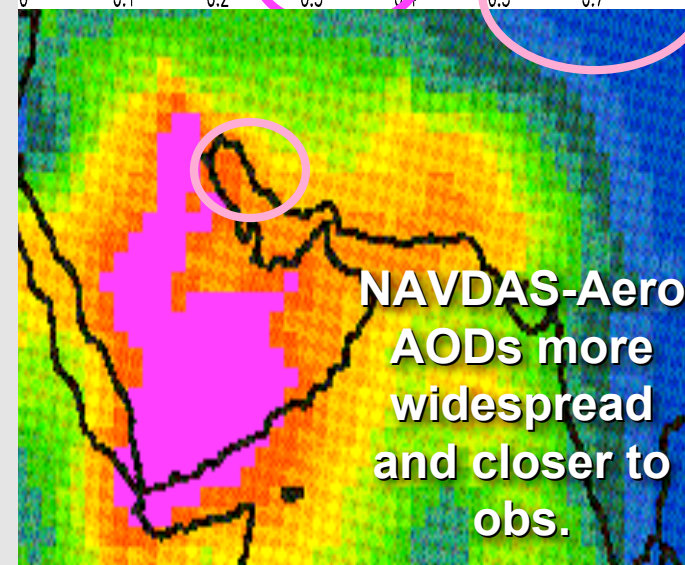
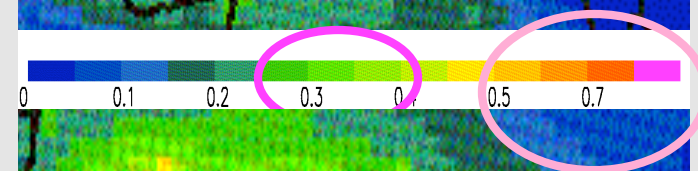
SeaWiFS Imagery shows widespread dust over SW Asia



NOAA AOD retrievals are 0.6 – 1.0 over N. Arabian Gulf



**NAAPS First
Guess AODs
generally too
low**



**NAVDAS-Aero
AODs more
widespread
and closer to
obs.**



Current And Future Research Efforts

- Ocean modeling and assimilation (NRL- Stennis)
 - NAVDAS and NAVDAS-AR will provide framework for ocean 3dvar and 4dvar
- Upper atmosphere assimilation and modeling (NRL-DC)
 - To 120 km and above
 - Ozone and GPS/RO assimilation
 - Higher-peaking SSMIS channels
 - Microwave limb sounder for temperature, humidity and ozone
- Prepare for assimilation of future satellites
 - METOP, NPP and NPOESS